Simulation of defect scattering efficiency on multilayer mirrors for EUV mask inspection tool

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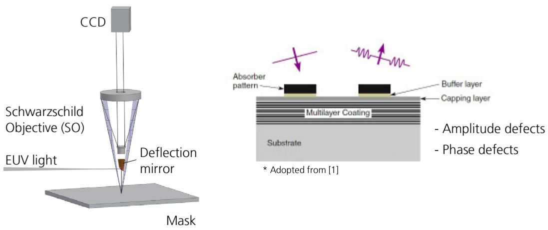
Introduction to EUV mask blank defects

- Laboratory scale defect localization tools for mask blank inspection at 13.5 nm are highly demanded and crucial to the successful implementation of next generation EUV lithography;
- Substrate roughness and remaining particles of size 30 – 150 nm are critical for structures quality during wafer manufacturing;
- Aerial scanning tools (Zeiss AIMS at 157nm) and phase measurement (Lasertec MPM at 157 nm) available, but not in EUV;
- Amplitude defects as particles on top of multilayer mirror (ML) and phase defects inside of ML have to be detected and localized at-wavelength, i.e. at λ = 13.5 nm



Defective multilayer mirror model

- ML modeled using Ito's [2] layers compression approach;
- Simulation model based on combination of rigorous electromagnetic field (EMF) computation with analytical thin-film computation and waveguide approach [3] ;
- For comparison, amplitude defects approximated by sphere and calculated by Mie scattering and Fraunhofer diffraction on pinhole

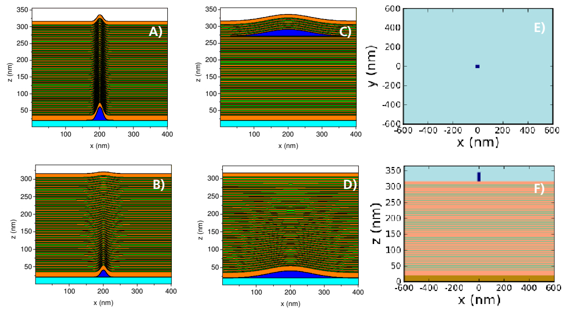


Figure 2. Examples of simulated ML defects: A) Substrate defect with Gaussian profile height h = 40 nm, FWHM = 20 nm, top layer superelevation SEL = 20 nm, $FWHM_{tl}$ = 20 nm; B) Substrate defect with h = 20 nm, FWHM = 20 nm, SEL = 5 nm, $FWHM_{tl}$ = 50 nm; C) ML defect at 34 layer, h = 20 nm, FWHM = 150 nm, SEL = 20 nm, $FWHM_{tl}$ = 150 nm; D) Substrate defect, h = 20 nm, FWHM = 150 nm, SEL = 0, $FWHM_{tl}$ = 0 nm; E) and F) Absorber structures

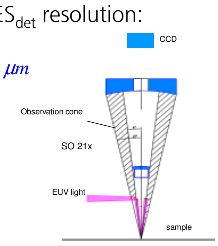
Imaging performance

- Schwarzschild Objective (SO) of magnification M = 21 in use, optimized for λ = 13.5 nm with NA_{min} = 0.11, NA_{max} = 0.21;
- State-of-the-art CCD sensor with pixel size px = 13.5 µm, QE = 0.4;
- Diffraction limited RES_{diff} and detector limited RES_{det} resolution:

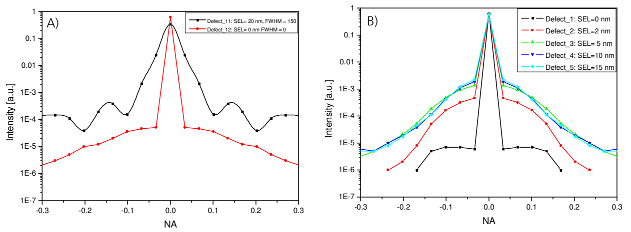
$$RES_{diff} = 1.22\frac{\lambda}{2\cdot NA} \approx 40\,nm \qquad RES_{det} \cong \frac{2\cdot pix}{M} = 1.2\,\mu m$$

- Depth of field DOF (with refractive index n = 1):

$$DOF = n\frac{\lambda}{NA^2} + \frac{n}{M\cdot NA}\cdot px \approx 306\,nm + 2.95\,\mu m$$



Simulation results



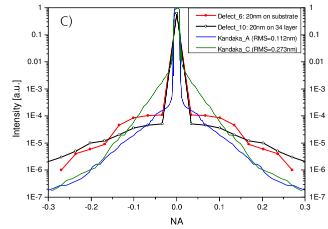


Figure 3. (A),(B) – Scattering efficiency for different defects on substrate and inside of MoSi multilayer;
(C) - Scattering efficiency in comparison to Kandaka's experimental scattering data [4].

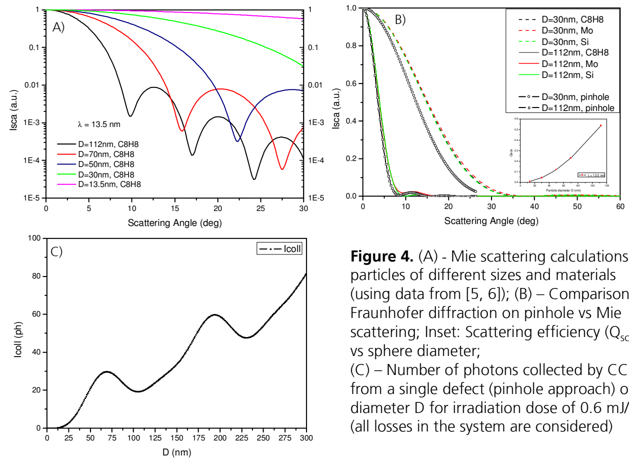


Figure 4. (A) - Mie scattering calculations for particles of different sizes and materials (using data from [5, 6]); (B) – Comparison of Fraunhofer diffraction on pinhole vs Mie scattering; Inset: Scattering efficiency (Q_{sca}) vs sphere diameter;
(C) – Number of photons collected by CCD from a single defect (pinhole approach) of diameter D for irradiation dose of 0.6 mJ/cm²
(all losses in the system are considered)

Conclusions and outlook

- At-wavelength metrology for defect inspection is mandatory for all printable defects (phase defects – buried defects in multilayer/ amplitude defects - particles)
- Compact table top EUV microscopes are usable for detection of all kinds of defects in bright and dark field operation
- Limited resolution determined by CCD pixel size and SO magnification
- Dark-field measurements together with illumination in reflection mode gives a chance to determine position of defect and to say "**Yes / No**" about defect presence on a mask blank of > 30 nm size

References

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